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The BOLL-WEEVIL PROBLEM

UNITED STATES DEPARTMENT OF AGRICULTURE
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WARNING.

THE present great interest in the boll-weevil problem in the Southeastern States has brought out a large number of proprietary preparations and machines, the sale of which is being vigorously pushed. This is a repetition of what has occurred in every region invaded by the boll weevil. During the first few years the farmers are exploited and many useless or practically useless devices are sold to them. In a few years, however, the organizations producing such devices go out of business. Their operations are especially important at the present time, since the losses caused by the boll weevil will be increased by the expense of buying nostrums of various kinds.

The claims for these preparations are not based on scientific tests, although in many cases the persons exploiting them are undoubtedly sincere in their belief that they will yield good results. Generally speaking, they are based on misinterpretations of what occurs in the field. To determine whether a remedy is effective, it is necessary to have control areas and to consider the effects of numerous cultural practices. It is very easy for an untrained observer to attribute to some preparation he has applied the beneficial results of some variation in climatic or cultural factors.

The Department of Agriculture and many of the State experiment stations have tested the new boll-weevil remedies which have been proposed from year to year, and many of those now being offered the public are not essentially different from the kinds that have been tested and discarded.

The Association of Southern Agricultural Workers at its convention at Memphis in February, 1923, discussed the whole problem of boll-weevil control, and, in addition to certain cultural methods, it recommended the consideration of three remedies.

This convention heartily indorsed the calcium arsenate dusting method in areas where the yield of cotton is high enough to warrant the expense. It also indorsed the Florida method for the region in which it has been proved to be applicable, and suggested extensive tests of this method in other regions of light yields.

The convention also called attention to the fact that the molasses-arsenate treatment, although not yet subjected to sufficiently detailed experimental tests to warrant its indorsement, has apparently given results over a wide area that warrant further consideration, and it therefore recommended thorough and immediate official tests of this method.

The State and Federal agencies are anxious to help the farmers by means of any new methods of controlling the boll weevil which may be discovered. As promptly as possible careful tests are conducted. The Department of Agriculture strongly recommends that farmers exercise due caution in spending money for new boll-weevil remedies. In all cases they should demand evidence of official tests and communicate with their experiment stations for detailed information regarding any of the new remedies. If anything of value is discovered by the State experiment stations or by the Federal department, prompt and widespread notice of the fact will be given the public. In the meantime any money spent for patented mixtures or machines will in all probability be wasted.

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THE BOLL-WEEVIL PROBLEM.

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ORIGIN, SPREAD, AND PRESENT DISTRIBUTION OF THE BOLL WEEVIL.

THE COTTON BOLL WEEVIL[1] is not a native of the United States. Its first home was undoubtedly in the plateau region of Mexico or Central America. Previous to 1892 the insect had spread through much of Mexico, but little is known regarding the extent or rapidity of this dispersion. The records indicate, however, that it probably had caused the abandonment of cotton in certain regions. About 1892 the boll weevil crossed the Rio Grande near Brownsville, Tex. It may have flown across or it is possible that it was carried over in seed cotton to be ginned at Brownsville. By 1894 it had spread to half a dozen counties in southern Texas. A preliminary examination, made during that season under the direction of Dr. L. O. Howard, Chief of the then Division of Entomology, by C. H. T. Townsend, showed the enormous capacity of the pest to do damage. Subsequent events have verified in every way the predictions that were made at that time, when the insect had not attracted much

[1] *Anthonomus grandis* Boh.; order Coleoptera, family Curculionidae.

attention in the South. Since 1894 the boll weevil has extended its range annually from 40 to 160 miles, although in several instances the winter conditions have caused a decrease in the infested area. During the first 10 years after its advent into this country the annual rate of spread of the weevil was 5,640 square miles. From 1901 to 1911 the annual increase in the infested territory averaged 26,880 square miles. In 1916 it reached 71,800 square miles. Of course, the figures given do not refer to the area in cotton. In many parts of the infested territory the area devoted to cotton is much less than 10 per cent of the total area.

The territory in the United States in which the boll weevil occurred at the end of the year 1922 is shown in figure 1. At the end of that year 614,213 square miles of territory had been infested by the boll weevil, leaving only about 91,000 square miles of cotton-producing territory uninfested. Practically 87 per cent of the Cotton Belt is now infested by the weevil, and the area now infested produces 95.99 per cent of the cotton crop of the Cotton Belt of the United States.

A form of the boll weevil is found in the mountains of Arizona feeding upon a wild plant related to cotton. This variety has been under observation for a number of years, and finally was noted in 1920 attacking cultivated cotton north of Tucson, Ariz., between that city and the Santa Catalina Mountains. The State of Arizona is attempting to eradicate this infestation by a noncotton zone in the infested district.

The boll weevil is known throughout the larger portion of Mexico and southward to Guatemala and Costa Rica. It is known to occur also in the eastern half of Cuba.

DAMAGE.

The losses caused by the boll weevil are both direct and indirect, and extend throughout practically the entire financial and economic structure of the Cotton Belt. It is impossible to estimate the losses due to depreciated land values, closing down of cotton gins and oil mills, and other indirect results of the weevil invasion. All estimates have been made entirely on the basis of the direct loss in nonproduction of cotton lint and seed. The Bureau of Crop Estimates of the United States Department of Agriculture in the fall of 1920 estimated an average annual loss for the last four years of about $300,000,000. Other estimates have differed somewhat, but certainly the annual direct loss is now well in excess of $200,000,000.

The damage in individual fields is influenced by many factors and varies widely, ranging from slight injury to complete destruction of the cotton crop. A fair idea of the possibilities of loss is afforded by the gains which have been secured in recent poisoning experi-

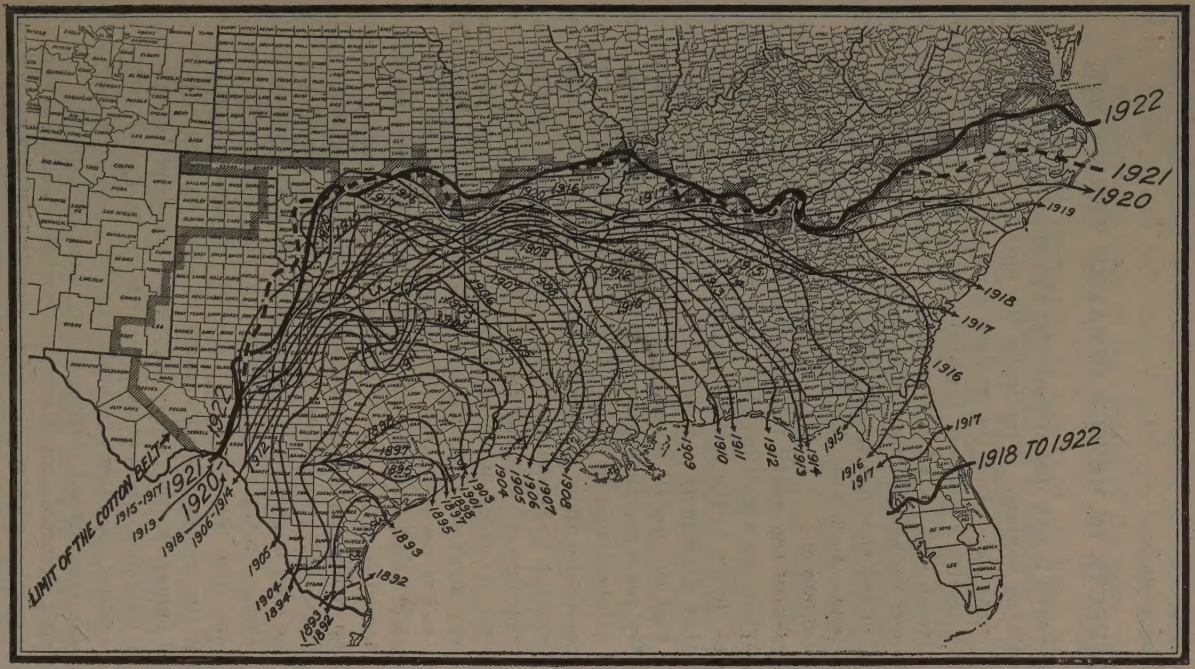

FIG. 1.—Map showing spread of the Mexican cotton boll weevil in the United States from 1892 to 1922, inclusive.

NOTE: The outer limit of the cotton belt advances or recedes slightly from year to year, and as shown on the map is not entirely accurate for 1922, as shown by the fact that in a few places the boll-weevil line is a little in advance of the indicated limit of cotton culture.

ments where weevil injury has been eliminated. Gains of five, six, or even seven hundred pounds of seed cotton per acre due to poisoning are not unusual, and in exceptional instances gains have exceeded one thousand pounds.

PROSPECTS IN NEWLY INVADED TERRITORY.

The boll weevil is now distributed over almost all of the important cotton-producing sections. Practically the only territory remaining uninfested is the zone along the western margin of the Cotton Belt. Some of this territory has been invaded in the past and the weevils have been driven back by adverse weather conditions. Whether the weevil will ever become seriously injurious in this territory is problematical, but it has shown marked ability to adapt itself to unfavorable conditions. Just how far this adaptation will extend it is impossible to predict.

The progress of the weevil invasion has caused one erroneous impression. When the weevil invades a new district complaint is made of its serious injury to the cotton crop during the first two or three years, and then little more is heard of it. This naturally leaves the impression that the weevil is seriously injurious in a new territory for only a few years and then passes onward. This impression, however, is not substantiated by facts. It is true that when weevils first invade a community there is nearly always more or less panic and a decided tendency to blame the weevil invasion for all short crops of cotton regardless of the real causes. Furthermore, the successful production of cotton in the presence of weevils requires somewhat different methods from those practiced before the advent of the weevil, and it usually takes the farmers two or three years to learn and adopt these methods. After a few years the farmers become accustomed to the weevil injury, learn to distinguish between loss due to the weevil and that attributable to other causes, and are able to reduce weevil injury somewhat by proper farming practices. The first fear has been overcome, and comparatively little is said on the subject. Farmers in the eastern portion of the cotton belt even express the idea that the weevil is no longer doing any damage in Texas. Yet the cotton-growing season of 1921 showed a total of more weevil damage in the State of Texas than that of any previous year. Once established in a community weevil injury will continue, and when weather conditions favorable to weevil survival and multiplication are experienced serious injury must be expected. Since one of the most favorable conditions for weevils is excessive summer rainfall, the regions with the heaviest precipitation during the cotton-growing months will suffer the greatest damage.

WORK UPON WHICH THIS BULLETIN IS BASED.

The danger from the boll weevil was appreciated from the beginning by the chief of the entomological service of the department. Work on the life history, although at first not extensive, showed the essential steps in the control of the pest. Later Congress made available large appropriations for the exhaustive investigation of the insect and of means of reducing its damage. Work was begun by the establishment of a laboratory at Victoria, Tex., and field experimental work was carried on in direct connection with the laboratory investigations. Later the headquarters of the investigation were moved from Victoria to Dallas, Tex., on account of the continued spread of the insect, and then to Tallulah, La. The Bureau of Entomology has conducted experiments during several seasons on a total of more than 50,000 acres of cotton located on well-known plantations throughout the infested territory. The special requirements in different regions have received particular attention.

Aside from the work relating directly to the boll weevil which has been conducted by the Bureau of Entomology, the Bureau of Plant Industry of this department has carried on investigations dealing with the breeding of cottons to obtain earliness and productiveness. The farm-demonstration service has carried the results of this work directly to the farmers throughout the South.

In addition to the work done by the Department of Agriculture, the State entomologists have dealt with the boll weevil in connection with the numerous other entomological problems of the States. They have contributed valuable results which have been incorporated in this bulletin.

DESCRIPTION AND LIFE HISTORY OF THE BOLL WEEVIL.

The adult boll weevil is about one-fourth of an inch long, varying from one-eighth to one-third of an inch, with a breadth about one-third of the length. This measurement includes the snout, which is approximately half the length of the body. Variation in size is due to the amount of food the insect has obtained in the larva stage. Individuals from bolls are therefore nearly always larger than those from squares. The color (grayish or brownish) depends upon the time that may have elapsed after transformation to the adult stage. The recently emerged individuals are light yellowish in color, but this changes to a gray or nearly black shade in a few weeks' time (fig. 2).

Hundreds of species of weevils in this country may be easily mistaken for the boll weevil. Many erroneous reports about the occur-

rence of weevils far outside the infested area have been due to this similarity. The only sure way to determine whether an insect is the boll weevil is to send it to an entomologist for examination. In the field the most conspicuous indication of the presence of the boll weevil is the flaring (fig. 4) and falling of numbers of squares. Unfavorable climatic conditions and careless cultivation, however, frequently cause great shedding, which is often mistaken for weevil damage. If excessive shedding be noted and the squares upon being cut open show a white, curved grub (fig. 5) that has fed upon the contents, there is little doubt that the boll weevil is the insect causing the damage.

FIG. 2.—Cotton boll weevil: *a*, Beetle, from above; *b*, same, from side. About five times natural size.

The boll weevil passes the winter as an adult or beetle. In the spring and throughout the fruiting season of cotton the eggs are deposited by the female weevils in cavities formed by eating into the fruit of the plant (see fig. 4). An egg hatches under normal conditions in about three days, and the grub immediately begins to feed. In from 7 to 12 days the larva or grub (fig. 3, at left) passes into its pupa stage (fig. 3, at right), corresponding to the cocoon of butterflies and moths. This stage lasts from three to five days. Then the adult issues, and in about five days begins the production of another generation. Climatic conditions cause considerable variation in the duration of the stages, but on an average it requires from two to three weeks for the weevil to develop from the egg to the adult. Males and females are produced in about equal numbers. The males feed upon the squares and bolls without moving until the food begins to deteriorate. The females refrain, throughout most of the season, from depositing in squares visited by other females, but late in the fall, when all of the fruit has become infested, several eggs may be placed in a single square or boll. As many as 15 larvæ have been found in a boll. The squares are greatly preferred as food and as places for depositing eggs. As long as a large supply of squares is present the bolls

FIG. 3.—Cotton boll weevil: Larva at left, pupa at right. About five times natural size.

are not damaged to any serious extent. The bolls, therefore, have a fair chance to develop as long as squares are being formed.

The cotton-boll weevil, so far as known, breeds in no plants other than cotton and the wild cotton of Arizona. At the present time, at least, the insect is restricted to the cotton plant as a means of development.

In laboratory experiments performed by the junior author, a weevil developed in the bud of a wild plant related to cotton. Under natural conditions it has not been found developing in that plant, but the experiments may indicate a tendency for the insect to acquire a new food plant. Adult boll weevils frequently have been found in

FIG. 4.—Weevil injury to cotton square. The square to the left has been punctured and shows typical "flaring" of bracts, while the one to the right is uninjured.

okra blooms, but repeated observations and experiments have failed to show that the weevil places its eggs in the pods or can develop in them. When confined in bottles, the adult weevil will feed on various substances, such as apples or bananas, but this is only under the stress of starvation.

The chief activity of the boll weevil is from 9 o'clock in the morning to 5 in the afternoon. It has been found in experiments performed in Louisiana that during this period of the day 65 per cent of the eggs are deposited. Eleven per cent of the eggs are deposited early in the morning—that is, from 5 o'clock to 9. There is some activity at night. Six per cent of the eggs are deposited between 8 o'clock at night and 5 o'clock in the morning.

Unlike some related insects, the boll weevil is not attracted to light. The fact that somewhat similar species do come to lights in great numbers at times has frequently caused the belief that the pest could be controlled by the use of trap lights.

An interesting habit of the boll weevil is to feign death—that is, to "play possum," or "sull," as it is popularly called. When disturbed, the insects usually contract their limbs and drop to the ground. This habit is not equally strong in all individuals.

The age to which weevils live varies according to conditions. During the winter the longevity is much greater than in the summer. During the summer season the majority of weevils do not live longer than 50 days. During the cooler part of the year many of them live as long as six months. The longest-lived weevil on record lived from December 10 to the following October, a period of about 11 months. Undoubtedly such prolonged life is exceptional in the usual form of the weevil. The Arizona weevil, however, has been known to survive for more than a year.

FIG. 5.—Cotton square showing larva of boll weevil in position. Natural size.

HIBERNATION.

As has been pointed out, the boll weevil passes the winter in the adult stage. At the time in the fall when frosts occur immature stages may still be found in the squares or bolls. If the food supply is sufficient, many of these immature stages continue their development at a very slow rate and finally emerge as adults. Thus there may be a somewhat continuous production of adults during the winter. Ordinarily, however, this is not the case, since the frosts that destroy the cotton generally kill practically all of the immature stages of the weevil.

With the advent of cool weather in the fall the adult boll weevils in cotton fields begin to seek protection against the winter. They fly from the fields in every direction, although their movements are governed partially by the prevailing winds. They may fly into hedges, woods, cornfields, haystacks, farm buildings, or other places. Specimens have been found in such situations, and also in considerable numbers in Spanish moss growing some distance above the ground on trees. A number of weevils also obtain hibernating quarters without leaving the cotton fields. These may crawl into cracks in the ground, under grass, weeds and other trash, and into the burrs from which the cotton has been picked. In some cases several thousand weevils per acre have been found hibernating in such situations. Here, however, the mortality is greater than where the protection is better. In fact, hibernation in the fields is not of great importance except in the more southern localities. That the majority of weevils which hibernate successfully do not pass the winter in the cotton fields has been shown by many experimental observations and is demonstrated every year in the infested territory by the appearance of the first damage in the immediate vicinity of woods and in other places where conditions for protection are favorable.

During the winter the weevils take no food and remain practically dormant. On especially warm days they may move about to a certain extent. During the very mild winter of 1906–7 hibernating weevils were found moving about more or less throughout the period from November to March.

The number of weevils that live through the winter has been determined very accurately for different conditions. It varies with the temperature and with the region. Heavily timbered regions, especially where Spanish moss occurs, show the smallest winter mortality. In Louisiana, out of 25,000 weevils, 2.82 per cent survived the winter of 1905–6. These weevils were placed under various conditions that must have approached those which the species encounters naturally. The winter referred to was practically a normal one so far as temperature and precipitation were concerned. In extensive work in Texas during the winter of 1906–7, out of 75,000 weevils 11.5 per cent survived. As in the preceding case, these weevils were placed under diverse conditions in different cages. These conditions ranged from the most favorable to the least favorable; that is, from an abundance of protection to practically none. The survival obtained was undoubtedly very close to that occurring under the diverse natural conditions of that winter. It must be emphasized that the winter of 1906–7 was abnormally warm. The average survival in experiments performed in Texas and Louisiana from 1906 to 1911 was 6 per cent, which must represent about the average survival occurring in nature.

From 1914 to 1920 a rather extensive series of cage experiments was conducted by the Department of Agriculture at Tallulah, La., utilizing from 20,000 to 30,000 weevils each year. These were placed in hibernation under a rather wide range of conditions, which probably represent a fair average of those found by the weevil in seeking hibernation quarters around the cotton field. The annual survival in these series varied from 0.3 per cent to 5.9 per cent.

Emergence from hibernation depends primarily upon temperature and rainfall in the spring, although some minor factors are concerned. In the southern portions of the Cotton Belt emergence usually begins from the first to the middle of March, but farther north it is somewhat later than this. Naturally, the individuals under the heaviest protection are affected latest by the temperature. The consequence is that emergence from hibernation is prolonged. It has been known to extend from the middle of March to the 28th of June, and in even more extreme cases from the middle of February to about the first of July. There is usually a comparatively short period during which the emergence is most rapid but this may be broken up into several such periods with intervals of slow emergence due to changes in weather conditions.

HOW NATURE ASSISTS IN DESTROYING THE BOLL WEEVIL.

Although the possible production of offspring in a single season by one pair of weevils has been estimated at 12,755,100, nature has provided several means of preventing such excessive multiplication. The most conspicuous of these are heat and insects that prey upon the weevil.

EFFECTS OF HEAT.

When infested squares fall to the ground they may become so heated that the larvæ are killed in a few minutes. The insect in the larva stage can not leave the square, as it has no means of locomotion whatever. Where the infested squares are subjected to the unobstructed rays of the sun the mortality is very high. This explains the well-known fact that dry seasons are unfavorable to the weevil and indicates great difficulty in controlling the insects in regions where precipitation is heavy. Occasionally as many as 90 per cent of the immature weevils in cotton fields inspected have been found to have been destroyed through this agency. The extent of destruction holds a close relation to the amount of shade. When there is no shade practically all of the larvæ and pupæ are killed outright. Some of the important means of control to be described later are based upon this consideration. (See p. 13.)

INSECT PARASITES.

The second of the means provided by nature for the control of the weevil is a large number of insect enemies. Forty-five species which prey upon the boll weevil are known. Of these, 23 are parasites, which by means of their special organs place eggs on the immature stages of the weevil within the square or boll. The young of the parasite develop by feeding upon the boll weevils, which they ultimately kill. Thus parasites instead of boll weevils emerge from the injured fruit. These enemies of the weevil have existed in this country for an indefinite time. Their natural habit has been to prey upon weevils more or less related to the boll weevil which have been present in this country for many years. They never feed upon vegetation. Since the boll weevil offered abundant and favorable opportunities for reproduction, while their original hosts were generally not very numerous, they have naturally turned their attention to the boll weevil. The weevil mortality due to these parasites is exceedingly variable. In many cases no mortality from parasites is observed, while on the other hand fields showing from 50 to 75 per cent of the weevils killed by parasites are by no means rare.

OTHER INSECT ENEMIES.

The boll weevil is attacked by a number of insects which are not parasites in a strict sense but prey upon it as food. The most important of these predatory enemies are ants. Twelve species are known to attack the weevil. They are the minute brown ants and the yellowish ants that occur frequently in cotton fields and are observed running over the plants or on the ground. Their work is not against the adult weevils, but against the immature stages in the squares. Some species devote their attention principally to the squares that have fallen to the ground, while others habitually seek the insects within the squares that remain hanging on the plants. The larva of the weevil, incased in a thin covering, offers food that the ants are not inclined to overlook. They gnaw through the thin shell inclosing the weevil larva, and the latter is soon destroyed. In some cases more than half of the immature stages in fields have been destroyed by ants alone. To find 25 per cent so destroyed is not a rare occurrence.

OTHER FACTORS IN NATURAL CONTROL.

Among minor factors in natural control may be mentioned the development of plant tissue known as proliferation, which sometimes crushes the immature weevils; and determinate growth of the cotton (the tendency to cease squaring about the middle or latter

part of the season), which may prevent the development of fall broods of the weevil. Birds are also agents in the destruction of the boll weevil, a fact which has been fully treated in the publications of the Biological Survey of this department.

VARIATION IN NATURAL CONTROL.

Winter killing during hibernation and summer killing due to heat are by far the most important types of natural control. If it were not for these agencies it would be impossible to raise cotton in the presence of the boll weevil. All control agencies, however, vary widely from field to field and season to season in their effect, and this explains the extreme variation in the amount of injury caused by the boll weevil. A mild winter followed by a rainy, cloudy summer favors rapid multiplication of weevils and the damage to the cotton crop is correspondingly increased, while the reverse weather conditions may practically prevent damage to the crop.

DISSEMINATION.

The boll weevil moves from place to place by flight. Although it is a weak flyer compared with many insects, it has been known to cover a distance of more than 40 miles in a very short time. Its flight can not be prolonged, but successive short flights, especially in connection with favorable winds, often carry the insect considerable distances. This is the case, however, only during the so-called dispersion period, which extends from about the middle of August to the end of the season. During the rest of the year the weevil is little inclined to fly. There is always a movement from fields in all directions in search of hibernating quarters in the fall and a corresponding movement from such quarters to the cotton fields in the spring. When the insects reach cotton fields in the spring there is little further movement until the general dispersion begins. Ordinarily between the middle of August and the 1st of September the weevil seems to be seized with the instinct to migrate. It was thought at one time that this movement was forced by excessive reproduction and took place only when all squares and bolls, or the majority of them, became infested. Investigations have shown, however, that the dispersion takes place frequently when the fields are only slightly infested. In other words, the insect has a well-developed instinct for extending its range into new territory. It is this instinct that has caused the extension of the infested area in the United States year by year. The weevil is governed in flight by the wind. If there is no wind, or only a light one, a weevil is as likely to fly in one direction as in another.

The fact that the weevil moves about very little except at one season is of great benefit to the planter. The movement referred to is of little importance after a region has become infested, because it does not begin until after the time when a crop normally is made. The limited movement during the rest of the year makes it possible for any individual farmer to obtain the best results from his own efforts in fighting the pest. The danger that his efforts will be thwarted by the arrival of weevils from fields where no precautions have been taken is not important enough to warrant any farmer in deferring action on account of the indifference of his neighbors.

METHODS OF CONTROL.

Control of the boll weevil is beset with many difficulties. The weevil's insidious methods of work in immature stages within the fruit of the cotton plant, the habit of the adult in seeking protection for the greater part of the time under the bracts of the squares, its enormous power of reproduction and adaptability to new conditions, all place it in a class by itself. These difficulties are further increased by many peculiar requirements of the cotton crop itself and the fact that a successful method of control must naturally be one which is practicable under the average conditions of cotton culture.

In spite of these difficulties, however, satisfactory means of control have been developed. These are the direct and the indirect methods, both of which are of vital importance. The importance of indirect methods is often more difficult for the farmer to appreciate than that of the direct; but, in reality, successful weevil control can not be accomplished unless full advantage is taken of every practical method, and the campaign must be based upon a combination of the different methods rather than concentrating all efforts on direct control.

The farmer is aided in his fight against the weevil by a number of important natural factors which tend to reduce the possible weevil damage. Some of the more important of these which must be taken into consideration in planning a fight on the weevil are as follows:

(1) *The weevil is practically dependent on cotton for reproduction.*

(2) *The mortality of the weevil during the winter is very high.*

(3) *Hot, dry weather during the summer exercises a tremendous control upon the weevil stages, while moist, cloudy weather removes this control and greatly accelerates multiplication.*

(4) *The weevil is attacked by many different species of insect enemies.*

(5) *The emergence from hibernating quarters during the spring is slow and prolonged until well into the summer.*

(6) *Early in the season, on account of comparatively low temperatures, the development of the weevil is much slower than during the midsummer months.*

(7) *The cotton plant produces many more squares than it can carry to maturity as bolls. This surplus is shed by the plant throughout the season, under normal conditions about 60 per cent of the fruit being shed.*

(8) *Up to a certain point weevil puncturing of fruit does not reduce the cotton crop, because large numbers of forms would be shed normally.*

(9) *The weevil has a decided tendency to seek moisture wherever it may be found on the surface of the plant.*

DIRECT CONTROL BY POISONING WITH CALCIUM ARSENATE.

Although the success of poisoning the weevil under certain conditions has been proved beyond doubt, there is danger that farmers may depend too much upon it and neglect the cultural practices which are absolutely essential in any system of weevil control. The basis of this control is still the cultural practices described in this bulletin. Poisoning is supplementary and depends for its success upon the other necessary steps. Unless the planter gives due attention to the seed, preparation, time of planting, and other recommendations made, it will be useless for him to depend upon poisoning to make a crop. The crop itself must actually be made by other expedients; poisoning is merely a device to protect it when it is made.

In the years which have elapsed since the advent of the boll weevil into the United States every conceivable means of direct control of the weevil has been tried repeatedly. Owing to the peculiarities of the weevil attack which have been mentioned, most of these attempts have been unsuccessful. Some methods were found which would control the weevil, but these were either impracticable or too expensive for use on a commercial scale. During comparatively recent years, however, a method of poisoning has been developed which has proved very successful. This consists of treatment of the plants with powdered calcium arsenate by a specialized method.

It has long been known that poisoning the boll weevil is possible to a certain extent, but on account of the peculiar habits of the insect it was difficult to develop methods for the application of the poison.

A profitable method, however, has now been developed by the Bureau of Entomology and is briefly described in the following pages. This has been tested for seven years and is now being adopted rather extensively by the farmers.

Motion pictures have been prepared that visualize the proper methods of poisoning and show the results which can be produced. Anyone interested can borrow copies of the films free of charge, excepting transportation charges, by application to the Office of Motion Pictures, United States Department of Agriculture, Washington, D. C.

The first question which occurs to the cotton farmer contemplating poisoning is whether it will pay to do so. From the following any cotton grower should be able to determine the question for himself:

It will pay to poison—

If the weevils are really injuring your crop seriously; and

If your land is sufficiently fertile to yield at least one-third bale per acre with weevil injury eliminated; and

If your farming organization is such that you feel assured that the poison applications will be made at the right time and in the right manner; and

If you are willing to spend the full amount necessary to provide an adequate supply of dusting machinery and poison.

You should not poison if the cost of the calcium arsenate, the cost of the labor to apply it, and the depreciation on the dusting machines will total more per acre than the current value of 100 pounds of seed cotton.

Hand guns should be figured as depreciating 50 per cent in a season and the larger machines about 25 per cent.

The next extremely important question is that of the dusting machinery which should be used.[2] Extensive experience has shown that it is impossible to get satisfactory results by using makeshift devices to apply the poison, and the only safe procedure is to provide an ample supply of the specialized dusting machinery which is now on the market for the treatment of cotton for the control of the boll weevil. Machines of various types, prices, and capacities are now being manufactured which meet the requirements and circumstances of almost all classes of growers. The following is a brief description of the several types and their uses:

The hand gun is the smallest type of cotton-dusting machine, and, as the name implies, must be carried and operated by the laborer. These machines are generally quite unsatisfactory, owing to their necessarily frail construction and laboriousness of operation. The selling price ranges from $12 to $20 each. *They should be used only*

[2] See Farmers' Bulletin 1319, Cotton Dusting Machinery.

when no other machine is suitable. Not more than 8 acres should be allotted to one hand gun, and it has generally been found inadvisable to attempt the treatment of more than 25 acres of cotton in one organization with hand guns.

The one-mule machine is the smallest of the traction type of dusters. The operator handles it as he would a walking cultivator or any other walking implement. The machine has two nozzles and will treat either two or three rows of cotton at a trip, thus covering from 15 to 20 acres of cotton in a night of operation. It should be allotted not more than 60 acres of cotton for treatment throughout a season. This machine is now selling at from $75 to $125.

The cart machine is a two-wheel, two-mule machine which straddles a row of cotton. It has three nozzles and will cover from 25 to 30 acres of cotton in a night of operation. It should be allotted not more than 100 acres of cotton for treatment through the season, and is the type most suitable for large farms. This machine is now selling at from $200 to $350.

In the early stages of the dusting work an engine power machine was tried and a few of these are still in use, but it has been found that they are generally too complicated for satisfactory operation except by expert labor. Still other types of machines to suit different conditions are in the process of development, but the present supply will meet almost any condition fairly well.

The following condensed rules have been prepared for the guidance of those planning to poison:

Use only pure calcium arsenate in the form of a dry powder.

Apply this only in the dust form.

Purchase this to conform to the following specifications:

Not less than 40 per cent total arsenic pentoxid.

Not more than 0.75 per cent water-soluble arsenic pentoxid.

Density not less than 80 or more than 100 cubic inches per pound.

Use only dusting machinery especially constructed for cotton dusting.

Poison only when the air is calm and the plants are moist. In most sections this means making only night applications.

Use about 5 to 7 pounds of calcium arsenate per acre for each application.

Start poisoning when the weevils have punctured from 10 to 15 per cent of the squares.

Keep your cotton thoroughly dusted until the weevils are under control. This usually means about three applications at the rate of one every four days.

Then stop poisoning until the weevils again become abundant.

If the weevils become abundant early enough to injure your young bolls, make one or two more applications late in the season.

If you have a heavy rain within 24 hours after dusting, repeat this application immediately.

Do not expect to eradicate the weevils. Poisoning merely controls them sufficiently to permit a full crop of cotton and you can always find weevils in the successfully poisoned field.

Keep your cotton acreage low and do everything possible to increase your yield per acre, as it costs just as much to poison one-quarter bale per acre cotton as bale per acre cotton.

Always leave an occasional portion of a cut unpoisoned for comparison with the adjoining poisoned tract. This will show how much you have increased your yield by poisoning.

INDIRECT MEANS OF CONTROL.

In addition to the use of poison there are numerous other practices which tend to reduce the weevil injury, some of which are of general value, while others can be used only locally. The following pages list a few of the more important of these measures. Even when poisoning is practiced the most thorough attention should be given to the indirect means of control, since they reduce the amount of poisoning which might be necessary and increase the profit which may be secured.

FALL DESTRUCTION OF INFESTED PLANTS.

One of the most important steps toward reducing the weevil infestation, when it can be practiced, is the destruction of the cotton plants in the early fall, before the weevils have hibernated. To be of the greatest value, however, the plants must be completely destroyed by fire or plowed under deeply before the first killing frost, and this limits the use of this control measure to the districts where conditions are such that the entire cotton crop can be picked in time to permit such an early plant destruction.

For many years preceding the development of the calcium-arsenate method of control, removal of the cotton plants from the field as early as practicable in the fall was advocated by this department as the most important step in controlling the weevil. The purpose of this operation is to destroy as many as possible of the immature forms of the weevil still remaining in bolls and squares. These immature forms, if undisturbed, transform into weevils which live over winter and lay eggs the following spring. Fall destruction of plants likewise eliminates hibernating places of the weevil in the field. (See "Destruction of Weevils in Hibernation.")

GRAZING.

In some districts where it is impossible to practice fall destruction of the plants, somewhat the same results can be accomplished by grazing the field with cattle, sheep, or goats. This is only a local measure, however, since the supply of live stock in regions where the bulk of the cotton crop is produced is insufficient for the purpose. Even where poisoning is practiced fall grazing is still advisable, and no danger need be apprehended of poisoning the stock, since there is rarely sufficient poison on the plants to injure stock, even im-

mediately after application, and, furthermore, a considerable period of time generally elapses between the last poison application of the season and the earliest grazing.

SPROUT AND VOLUNTEER COTTON.

Considerable local difficulty in the control of the boll weevil is experienced in southern Texas, and occasionally in Louisiana, owing to the presence of stumpage or sprout cotton. Sprout plants are sometimes encouraged because they produce a small but very early crop. This may have been defensible before the advent of the boll weevil, but at present the practice is undoubtedly the worst that could possibly be followed. The weevils seek out these large plants in the early spring and produce progeny much earlier than they otherwise could, and these progeny infest the planted cotton at an abnormally early date. Volunteer cotton causes the same results over a considerable portion of the cotton belt. The cottonseed scattered about seed houses and gins and along roadsides frequently produces plants which furnish early season breeding places for the weevil. Needless to say, all such plants should be destroyed.

DESTRUCTION OF WEEVILS IN HIBERNATION.

It is often possible for the farmer to reduce considerably his spring weevil infestation by proper winter clean-up measures around his fields. Since the weevils will hibernate successfully in any trash or rubbish, it is a very good practice to burn over or clean up around the cotton field during the winter, especially the fence rows and ditch banks.

In addition much can be accomplished by the elimination of hibernation quarters. Especially along the more northerly portions of the weevil zone, the most successful hibernation is largely confined to the timbered areas, and as a result serious weevil injury is only experienced in the fields adjoining such timber. Under such conditions it is of the utmost importance to plan all clearing operations so that the open areas for cultivation are consolidated into as large tracts as possible, thus increasing the amount of land which is sufficiently distant from timber to suffer a minimum amount of weevil injury.

LOCATING FIELDS TO AVOID WEEVIL DAMAGE.

Nearly every farmer who has been raising cotton for a few years in the presence of the boll weevil knows that there are certain fields on his place where the weevils always appear first and in greatest numbers. With this information as a basis, it is sometimes possible to reduce the damage by refraining from planting cotton in such

fields and planting the more distant fields. This practice, however, is advisable only when no attempt is made to control the weevil by poisoning. These fields adjoining timber where the weevil infestation is heaviest are usually the new lands of the place and are thus the most fertile and capable of producing the best cotton crop if the weevil injury is eliminated. Furthermore, when such fields adjoin hibernation quarters, the weevils concentrate on them instead of scattering over larger areas and they serve to a certain extent as trap crops, making it possible to poison the weevils on these fields and thus prevent their spread over the remainder of the crop.

PROCURING AN EARLY CROP OF COTTON.

The foregoing facts relative to the life history, hibernation, emergence, and multiplication of the weevil show very plainly the importance of producing the cotton crop just as early in the season as possible. In reality the production of cotton in the presence of weevils is nothing more or less than a race between the setting of bolls on the plant and the multiplication of the weevils, and everything possible should be done to aid the cotton plants in winning this race. The following are some of the more important steps which may be taken.

EARLY REMOVAL OF PLANTS AND PREPARATION OF LAND.

The first step in procuring an early crop is the early removal of the plants, so that the land may be plowed during the fall and winter and the seed bed thoroughly prepared. Just how much can be done is of course a problem for the individual farmer to determine and depends largely upon labor and weather conditions, but the importance of a well-prepared, solid seed bed can hardly be overestimated. Furthermore, unfavorable weather conditions shortly before planting often prevent plowing at that time, and early preparation does away with this risk.

USE OF EARLY VARIETIES OF COTTON.

One of the most important steps which have been taken to reduce the weevil damage has been the development and introduction of varieties of cotton which mature their crops earlier in the season than those varieties which were planted before the weevil invasion. The variety to be planted in order to obtain a profitable crop under weevil conditions will depend upon a number of factors as well as on the severity of the infestation. The soil, climate, and other factors must be considered. In many localities it is extremely important to select varieties which are resistant to diseases. The first

effect of the boll weevil invasion was to cause the abandonment of longer staple and large-boll varieties of cotton and the adoption of small-boll, early varieties of very short staple cotton, such as King and its derivative Simpkins, etc., in the mistaken belief that only such cottons could be successfully grown under boll-weevil conditions. This resulted in the deterioration of the average quality of the cotton grown in many sections, and, consequently, in loss of market prestige formerly enjoyed. Now, however, numerous varieties of better staple cotton have been developed which mature sufficiently early and produce as well as any of the shorter staple varieties, and these are being rapidly adopted. The Triumph variety is one of the best known for the western portion of the infested territory. Among the others which are well adapted to practically the entire Cotton Belt are Cleveland Big Boll, Cook's Improved, Rowden, Toole, Brown, Lone Star, Trice, Columbia, and Acala. There is believed to be no advantage in growing an extremely early short-staple cotton in preference to cottons of this better type in any section. On the contrary, the shorter staples are more and more being discriminated against in the market.

The long-staple cotton situation is particularly interesting. The Upland long staples, which were cultivated when the weevil arrived, were slow-maturing, nonprolific varieties with a very thin boll wall, and were thus subject to a maximum amount of weevil damage. The weevil soon eliminated practically every one of these varieties, and for some time it appeared that the production of long-staple cotton would be practically prohibited. This situation, however, has been met by the development of several long-staple varieties which are prolific and reasonably early. Among the best known of these are such varieties as Express, Webber, and Meade.

It should be thoroughly understood that the selection of the cotton variety is purely a local proposition, and the farmer is warned against the extensive planting of a new variety (merely because it has done well elsewhere) before he has tried it on a small scale under his own conditions. Whenever possible, seeds should be obtained from local planters who have given attention to varietal selection. Varieties introduced from different sources require several seasons to adjust themselves to new conditions. The use of seed simply because it comes from a northern locality is a practice which frequently has done great injury. The only case in which the introduction of northern seed is justified is where the seed represents a variety which has been improved with reference to early maturity. Even this practice is not to be recommended except as an emergency measure when locally improved seed is not available.

EARLY PLANTING.

Another step to be taken in obtaining an early crop, and fully as important as those that have been mentioned, is early planting. No set rule can be laid down as to the proper date for planting. There is much variation in the seasons. Sometimes it is impossible to place the fields in readiness as early as is desirable, and much of the effect of early planting is lost unless the seed bed is in good condition. Rather than plant abnormally early it would be better to improve the seed bed. It is not recommended that planting be done at dangerously early dates. Of course, it is possible to plant entirely too early, so that the plants become stunted during the early days of their growth, and planting should not be done so early as to have this effect upon the plants.

The following additional remarks about the time of planting are quoted from Farmers' Bulletin 501:

> In addition to the use of early varieties and of cultural methods that favor a rapid development of the crop, it is important to plant early—that is, as early as may be consistent with the fundamental object of avoiding weevil injury by shortening the crop season. The difficulty is to determine when the cotton ought to be planted to secure the best results, for the same date will not be most favorable in different localities or even in the same locality in different seasons. The ideal solution of the problem would be for the members of each cotton-growing community to begin planting at the same date.

FERTILIZERS.

The intelligent use of commercial fertilizers is an important step in the profitable production of cotton under boll-weevil conditions. In the western part of the Cotton Belt seasonal conditions are usually such as to make the use of fertilizers of doubtful value, and in some other areas their use seems to be of minor importance, but outside of these areas commercial fertilizers properly used will both hasten maturity of the cotton and materially increase the yield.

On most soils a fertilizer containing high percentages of quickly available nitrogen and of acid phosphate seems to give best results under boll-weevil conditions. On very sandy land, or soils on which cotton is subject to rust or wilt, some form of potash should also be included in the fertilizer used.

Many successful cotton growers are now convinced by their own experience that, by practicing good cultural methods, and with the use of from 500 to 600 pounds per acre of a fertilizer, composed of one-third nitrate of soda and two-thirds 16 per cent acid phosphate, applied before planting, they can grow profitable crops of cotton in spite of heavy weevil infestation, even without the use of poison or other direct means of weevil control.

The building up of soils by the use of legumes, planted either with corn or solid, is of the greatest importance. Commercial fertilizers if used will in all cases give much greater results on lands made more fertile by this practice or may even be unnecessary.

In the alluvial soils of the Mississippi Valley remarkable results in obtaining increased yields under boll-weevil conditions have followed the growth of cowpeas for a single season. The use of cover crops is also of great importance and worthy of the careful attention of all planters in the infested territory where the practice can be fitted into their plan of operations.

The relation of fertilizers to the determinate growth of the cotton plant should be carefully considered. With certain varieties and certain soils the plants have a decided tendency to cease squaring about the middle or latter part of the season and to mature at that time. This habit has been termed the "determinate growth" of the plant. According to the time it occurs, this may be an advantage or disadvantage in the fight against the weevil. If it occurs too early it is a decided disadvantage, because this cessation of squaring produces a food shortage which causes the weevils to attack the bolls with abnormal severity. Consequently, it is very desirable to have the cotton continue squaring long enough to protect the full crop of bolls to maturity. After the bolls are safe, however, the squares are a liability rather than an asset, since a large number of weevils are produced from them and enter hibernation well prepared for survival. In utilizing fertilizers the farmer should plan to supply his weevils with an abundance of food until his crop of bolls has matured beyond the point of injury and then the sooner his cotton stops squaring the lighter his infestation will be the following season.

SECURING A FULL STAND OF COTTON.

There have been many tests and much discussion regarding the spacing of cotton and its relation to boll-weevil control. The most profitable spacing will doubtless vary somewhat with the season, soil, variety, and other conditions. It has been shown conclusively, however, that the number of plants per acre has a very definite relation to yield, especially under weevil conditions. The general practice has been extremely careless, and poor stands of cotton are too frequently secured. Station tests and practical farm experience have indicated the value of thicker spacing under weevil conditions than had been the rule before. Spacing from 9 to 12 inches in the drill or row with two or more plants to the hill has usually given the highest yields in station tests conducted during the past few years, and it is believed that this spacing may be safely recommended for general use. Width of rows should be no more than necessary for proper and easy cultivation.

CULTIVATION.

During the growing season of the crop the fields should be very carefully cultivated, otherwise most of the benefits of early preparation, early planting, and fertilization may be lost. In case of unavoidably delayed planting the best course to pursue is to cultivate the fields in the most thorough manner possible. Under most conditions the old plantation rule "once a week and one in a row" should be applied. This will not result in the direct destruction of many weevils, but it causes the plants to continue uninterruptedly in their growth. By all means such operations as deep cultivation and cultivation close to the plants, which cause shedding, should be avoided. In many instances a fair crop already set and beyond danger from the weevil has been lost by running the plows so close that the side roots were cut and the plants made to shed practically all the fruit. When this happens during the middle or latter part of the season the weevils will certainly prevent the putting on of any more fruit. The general practice of "laying by," by scraping the middles with a wide sweep, leaves a hard surface which causes loss of moisture and shedding. Where the weevil occurs, every precaution must be taken to avoid shedding, as the insect will prevent the maturity of the later fruit and, moreover, will be forced to attack bolls which otherwise would not be injured.

The value of late cultivation has often been discussed. Prior to the advent of the weevil it was an almost universal custom to "lay by" the cotton crops well before the time when the last bolls were set. This practice has been very largely abandoned, however, owing to dire necessity. The importance of keeping the cotton squaring long enough to protect the bolls until safe from injury has been mentioned, and the best way to accomplish this result is to continue cultivation until fairly late in the season, at least two or three weeks beyond the usual time of "laying by." This is, of course, a somewhat dangerous practice, since it is a critical period in the bolling of the cotton plant, and it is very easy to bring on absolute disaster to the crop by improper cultivation at this time. Consequently, all carelessness at this season should be avoided and the plow should not be run too deeply or too close to the plant, or excessive shedding will result. Careful late shallow cultivation is to be very strongly recommended.

DRAINAGE.

The foregoing paragraphs have dealt largely with the necessity of an early crop and have emphasized the importance of expediting the crop by early preparation of the seed bed, early planting, and frequent cultivation. These operations, however, can only be successfully conducted under conditions of good drainage. It is practically

impossible to raise a profitable crop of cotton on poorly drained land. On the other hand, the value of good drainage is everywhere apparent. It makes possible the earlier planting of cotton, early germination, and rapid, frequent cultivation. Furthermore, the ground dries out more rapidly after a rain, which increases the control of the weevil by sunshine.

INEFFECTIVE METHODS OF CONTROL.

The extreme seriousness of the boll-weevil problem has called forth hundreds of suggestions in control. These have included changes in manner of planting, attracting the insects to food plants or lights, soaking the seeds to make the plants distasteful, sprays, machines, chemical fumes, and the planting of various plants supposed to be repellent. In many cases these suggestions have been made without due understanding of the habits of the weevil. In other cases practical features, such as the cost of application, have not been considered. The following paragraphs deal with some of the principal ineffective methods that have been proposed.

LATE PLANTING.

Late planting is foremost among the futile means of control. At various times it has been suggested that late planting, especially if following early fall destruction, would so lengthen the hibernating period that no weevils would survive. Very numerous experiments in the field and in cages have proved that the weevils in considerable numbers are able to survive from any reasonable time of early destruction in the fall to beyond the date in the spring when any return whatever could be expected from planting cotton, even if the weevils were entirely eliminated. In a field experiment in Kerr County, Tex., the plants were removed very thoroughly early in November. Neither stumpage nor volunteer plants were allowed to grow during the winter. No other cotton was planted within 9 miles. On the experimental field, planting was deferred until June 10. In spite of this fact weevils appeared as soon as the plants were up and multiplied so rapidly that the production was not sufficient to warrant picking. Similar experiments under different conditions by the State Crop Pest Commission of Louisiana[3] agree in every way with those of the Bureau of Entomology in Texas.

The habits of the insect explain the failure of late planting. In many cage experiments it has been found that the last emerging weevils in the spring appear well into the month of June. In fact, emergence has taken place as late as the 27th and 28th of June.

[3] Described in Bulletin 92 of the Louisiana Agricultural Experiment Station, published in 1907.

Without any food whatever the emerging weevils are able to survive for some time. The maximum known survival of any hibernated weevil without any food whatever after emergence was 90 days, and a considerable number lived from 6 to 12 weeks after emergence. This ability to survive without food, together with the late emergence, renders it entirely out of the question to exterminate the boll weevil by late planting. Moreover, a considerable number of volunteer plants, which come from seed scattered accidentally or blown from the bolls during the fall, are always to be found along roads, turn rows, in cotton fields, and elsewhere. These plants, starting early in the spring in such numbers as to be beyond control, would furnish a means for the weevils to subsist to the time of planting, however late it might be. In 1906, for instance, at Dallas, Tex., volunteer plants appeared in the spring at the rate of about 1,000 per acre. An investigation showed that the number of such plants increases to the westward as the climate becomes drier. Nevertheless, numbers of plants were found near Memphis, Tenn., and Vicksburg, Miss., in a region of more than 50 inches of annual precipitation. Similar observations have been made each season since 1906.

WEEVIL AND SQUARE COLLECTION.

The possibility of weevil control by hand picking of the adult in the early spring and of the infested squares later in the season has been thoroughly tested on numerous occasions. Undoubtedly this method is efficient when practiced with sufficient thoroughness, but numerous attempts to carry it out on a practical scale have shown that the labor difficulties are almost always prohibitive. This work is of value only comparatively early in the season, and thus falls at the same period when there is a very heavy demand for the labor for other purposes, and it is generally impossible to collect the weevils or infested squares without neglecting other more important work. Consequently, this procedure is recommended only when the cotton acreage under cultivation is small enough to permit the usual labor on the plantation to do the work without interference with cultivation or other important work. Where square picking is relied upon for weevil control, it should be begun as soon as the first punctured squares are noticed and every effort made to keep all punctured squares picked and destroyed for a period of about 30 days thereafter. It is not believed that it will usually be profitable to continue this work for a longer period.

Many attempts have been made to collect the weevils by means of mechanical devices. Hundreds of such devices have been tested and all are to be condemned. They do not collect an appreciable number of weevils unless they are so violent in the agitation of the cotton plant that they are actually injurious to it.

TRAP ROWS.

The idea of attracting weevils to a few early plants or trap rows has frequently been advanced. Practical experience, however, has shown that the only possibility of success in such a procedure lies in the use of entire fields adjoining hibernation quarters, the fields to be poisoned later (see pp. 18–19). The use of only a few rows as a trap crop has been found to be absolutely valueless.

ATTRACTION TO LIGHTS.

Many insects more or less resembling the boll weevil are attracted to lights. Many attempts have been made to destroy the cotton pest by taking advantage of this supposed habit. The boll weevil, however, is not attracted to lights. Numerous tests have been made in which many thousands of other insects were collected around strong lights in cotton fields, but not a single boll weevil was found, in spite of the fact that there were multitudes of these pests in the fields surrounding the lights.

CHEMICAL TREATMENT OF SEED.

Any money expended by the farmers in attempting to destroy the boll weevil by soaking the planting seed in chemicals in the hope of making the plants that are to grow from them distasteful or poisonous to the insects would be entirely wasted. The same remark applies to the various proposed treatments of the plants or soil with chemicals which are supposed to be taken up by the plants to the detriment of the weevils feeding upon them.

TOPPING OF PLANTS.

The topping of plants is sometimes recommended for fields infested with boll weevils. This practice generally results in more harm than good, since it removes a portion of the plants upon which the weevil is most dependent for food during the latter part of the season, and furthermore practically always produces an exceedingly dense foliage growth which greatly reduces the sun control of the weevil stages and promotes such dangerous diseases as boll-rot.

SWEETENED POISONS.

Many attempts have been made to make poisoned substances attractive to the weevils by introducing sweets and other ingredients. Some known sweets, such as honey, have a slight attraction for the weevil, but not enough to assist in practical control. From recent tests, however, it appears that during the early season when the plant is small, and especially during dry weather, the use of some poisoned sweet mixture exercises a considerable degree of control on the weevil. In some districts many reliable planters claim a very definite benefit

from the use of mixtures of calcium arsenate and molasses. In other districts, however, it has been shown quite definitely that the use of the dust application of poison is preferable even during this period.

CONTACT POISONS.

Poisons designed to kill the boll weevil by suffocating them have been proposed. They can not, of course, be effective against the immature weevils within the cotton fruit. Normally, also, the adult weevils are found inside the bracts of squares, where they can not be reached by sprays. Numerous chemicals have been found which, if placed directly on the weevil, will cause immediate death, but this does not mean that these chemicals are of the slightest value when applied in the field. In the first place, they are nearly always exceedingly injurious to the cotton plant, and furthermore, when applied to the plant under field conditions, do not come in contact with the weevils sufficiently to kill any appreciable number. In spite of the numerous chemicals tested, not a single contact poison has been found to have any practical value in field use against the weevil.

REPELLENTS.

In the same way it has been claimed that numerous chemicals, fumigants, etc., have a repellent value against the boll weevil. Almost every conceivable compound has been tested for this action and not a single one has been found which had the slightest repellent action against the weevil.

OTHER PROPOSED REMEDIES.

Many other remedies have been suggested for the weevil. Literally hundreds of these have been carefully investigated, and it has been found that the claims of their advocates were based on faulty observations or careless experiments. It is true that many of them when placed directly on the weevil will cause immediate death, but they are still found valueless when used in the field. The claims made at different times of the repellent power of tobacco, castor-bean plants, and pepper plants against the boll weevil have no foundation whatever. In fact, none of these plants has the least effect in keeping weevils away from cotton.

EFFECT OF METHODS OF CONTROL OF THE BOLL WEEVIL ON THE CONTROL OF OTHER INSECTS.

THE COTTON BOLLWORM.

The most important enemy of cotton in the United States, aside from the recently introduced pink bollworm [4] and the boll weevil, is the bollworm,[5] which has existed in this country for many

[4] *Pectinophora gossypiella* Saund. [5] *Heliothis obsoleta* Fab.

years and frequently reduces the crop very considerably. Its annual damage to cotton in the United States has been conservatively estimated at more than $8,000,000. This insect is also a very important enemy of corn, tomato, okra, cowpeas, and some other crops. Careful studies of the bollworm were conducted by Dr. A. L. Quaintance, of the Bureau of Entomology, in connection with large-scale field experiments in many localities. The conclusions drawn from this practical work were that the essential steps to be taken in the control of the boll weevil are exactly the ones that should be followed in the warfare against the bollworm. The following is the statement by Doctor Quaintance on this subject:

> The steps in the production of early cotton include the principal recommendations for the growing of cotton in the presence of boll weevils. It is therefore seen that injury from the cotton bollworm and the cotton boll weevil may be best avoided by the adoption of one and the same course of improved farm practice. The spread of the latter species will render imperative the adoption of these methods in profitable cotton culture, and along with this change the ravages of the bollworm during normal seasons should become less and less.

The development of weevil poisoning adds another interesting phase to the question of control of the cotton bollworm. Years ago experiments were conducted which showed that a certain poisoning procedure would control the bollworm, but it was found that the bollworm damage was not sufficiently heavy to justify the expenditure necessary for this poisoning. Since the development of weevil poisoning, however, it is interesting to note that the procedure recommended for the two insects is practically identical; thus satisfactory bollworm control should be secured as a supplementary benefit to be derived from weevil poisoning.

THE COTTON LEAFWORM.

The relation between the cotton leafworm [6] or the so-called "armyworm" and the control of the cotton boll weevil deserves special attention.

Years ago the efforts of entomologists and planters were directed toward some means of destroying the leafworm. The use of Paris green and other poisons was found to be very effective. The complication of the situation since the arrival of the boll weevil has caused a decided change of attitude toward the leafworm. This insect usually does not become abundant until late in the season; and unless the boll weevil is controlled, the cotton plants are not setting any bolls at that time. Consequently, the leafworm does not injure the crop and is really often beneficial, because it removes the food supply of the boll weevils. The use of calcium arsenate to control the boll weevil also prevents leafworm damage; thus such poisoned

[6] *Alabama argillacea* Hübner.

fields are not subject to injury until boll-weevil poisoning has been stopped. Then, the question of whether or not additional applications should be made to control the leafworm is to be determined entirely on the basis of the young fruit on the plants and the possibility of any of this fruit reaching maturity before frost if protected from damage. Under such conditions poisoning solely for the control of the leafworm is very seldom necessary or advisable.

THE COTTON APHIS.

In some districts, it has recently been found that the use of repeated applications of calcium arsenate causes a large increase in the numbers of the cotton aphis, or "lice," and on some occasions they have become sufficiently abundant to injure the crop in both volume and grade. So far, such instances have been localized and sporadic, and it is not possible at this moment to say just how general this condition may become. Investigations are under way to determine the factors involved in this development. Studies are also being conducted to determine means of control for the aphis, and results so far indicate that complete commercial control can be secured by a single application of nicotine dust. So far, there seems little likelihood that this will become necessary except possibly in certain restricted regions.

SUMMARY OF CONTROL MEASURES.

The following is an outline of the practical methods of controlling the boll weevil described in detail in the preceding pages. These methods are based upon extensive study and much field experimentation. They represent practically all that is known about combating the most important enemy of the cotton plant. They form a system composed of several parts. A cotton planter can insure success in proportion to the extent to which he combines the different essential parts.

(1) When possible practice early fall destruction of the cotton plants.

(2) Destroy as many weevils as possible in hibernation by cleaning up and burning over hibernation quarters. Also, clear land whenever possible to consolidate open areas and reduce fields subject to early, heavy infestation.

(3) If you are not poisoning, plant in the fields located in situations where weevil damage will be minimized. If you are poisoning, however, plant your fertile soil adjoining hibernation quarters and concentrate your efforts on thorough control of the weevils in these fields.

(4) Prepare the land early and thoroughly in order to obtain an early crop. This means fall plowing and winter working of the land.

(5) Determine the best distances between the rows and between the plants by experiments on local soils. Once this is determined make every effort to obtain a perfect stand at the desired spacing.

(6) Insure an early crop by timely planting of early maturing varieties and by fertilizing when necessary.

(7) Continue to procure an early crop by careful chopping to a stand and early and frequent cultivation. Do not lose the fruit the plants have set by cultivating too deeply or too close to the rows.

(8) Study the instructions governing poisoning very carefully, and if your conditions seem suitable for profitable work poison the weevils thoroughly with powdered calcium arsenate.

(9) Before attempting to poison, obtain from the Bureau of Entomology full and detailed instructions based on your local conditions.

FLORIDA METHOD OF BOLL-WEEVIL CONTROL.

Recently the Florida Agricultural Experiment Station has published a bulletin, No. 165, dealing with experiments by G. D. Smith, under the direction of Dr. Wilmon Newell. In these experiments, which were conducted in northern Florida, the treated fields averaged 439 pounds of seed cotton per acre; the untreated checks averaged only 164 pounds of seed cotton per acre, or an average increase of 275 pounds of seed cotton per acre in all tests. The average cost of treatment for the entire season was $1.57 per acre.

This new method consists of the removal and destruction of all squares present on the plants at a time when about two squares per plant are present. This operation destroys a large percentage of the weevils and is immediately followed by a thorough dusting to poison the terminal buds, where the remaining weevils are forced to feed.

This announcement is particularly important because it apparently offers a means of controlling the boll weevil on low-yielding land.

Dr. Wilmon Newell, plant commissioner of Florida, has issued the following note relating to this method:

The method of boll-weevil control described in this publication (Fla. Sta. Bull. No. 165) has been thoroughly tested in the field in Florida, and is recommended for use of cotton growers of that State alone.

Farmers in other States should not attempt to make use of the control method unless the date of completion of spring emergence of the weevil is definitely known. This information should be secured from your own State entomologist or experiment station, whose advice should be sought before attempting the use of this method of boll-weevil control.

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